ART. XI.—*The Sun and Stars photometrically compared;* by ALVAN CLARK.

IF we place a lens of known focal distance, one foot for instance, between the eye and a star of the first magnitude, or one of any considerable brightness, with conveniences for guiding its movement in distance, to any point where it may be needed, and find the star just visible, or reduced to a sixth magnitude, when the lens, if a convex, is eleven feet from the eye, it becomes clear that, since the star has undergone a reduction of ten diameters, it would be visible, if removed in space to ten times its present distance. This, however, is on the supposition that no absorbing or extinguishing medium exists in space.

If a concave lens be employed, the measure must be commenced at the lens itself, but if convex, at the focal point; or once the focal distance must be subtracted from the measure, and the number of focal distances remaining corresponds to the number of reductions under which the object is viewed.

Castor is visible, when reduced,	10·3	times
Pollux,	11	"
Procyon,	12	"
Sirius,	20	"
The full Moon,	3,000	"
The Sun,	1,200,000	"

I have actually seen the sun under such a reduction; attended by circumstances which have led me to believe that it is about

the limit at which the naked human eye could ever perceive this great luminary.

I have an under-ground, dark chamber, 230 feet in length, one end terminating in the cellar of my work-shop, and the other communicating with the surface of the ground by a vertical opening, one foot square, and five feet deep. In a moveable partition, between this opening and the end of the chamber, a lens of such focal distance as I choose can be inserted. A twentieth of an inch focus I have employed, of the best finish possible; its flat side cemented to one face of a prism with Canada balsam.

No light whatever can enter the dark chamber, except through this little lens. A common, plane, silvered, glass mirror, placed above-ground, over the vertical opening, receives the direct rays from the sun, and sends them down into the prism of total reflexion, by which they are directed through the little lens into the chamber.

An observer, in the cellar, 230 feet distant, sees the sun reduced 55,200 times; and its light, in amount, varies but little from that of Sirius.

Upon a little car, moveable in either direction, by cords and a pulley, is mounted another lens, with a focal distance of six inches. The eye of the observer is brought into a line with the lenses, or so near it, that he sees the light through the six inch lens; then, by the cord, he sends the car into the chamber, to the greatest distance at which he can see the light, like that from a star of the sixth or seventh magnitude.

At noon, March 19th, with a perfectly clear sky, I found the sun visible through the six inch lens, when it was removed to the distance of 12 feet from the eye. The distance between the lenses being 218 feet, the reduction by the small lens, if viewed from the point occupied by the six inch lens, would be 52,320 times; and that again by the six inch, distant from the eye 12 feet, or 24 times its focal distance, is reduced 23 times; making the total reduction 1,203,360 times.

It becomes now an important matter to ascertain as nearly as possible the proportion of light lost, by and through the media above described; the looking-glass, the prism, and two lenses; though joining the little lens with balsam to the prism, it may be regarded as one piece.

I have only investigated by experiments with artificial lights; but I find, when the mirror is placed at the angle which the sun requires at the date above given, the difference in the distance at which a direct light, and the same light reflected, is brought to a *minimum visibile*, does not exceed one-eighth part of the entire distance, and could not reach one-seventh, when the prism and lenses were interposed.

Again; the image of the highly illuminated atmosphere, for some degrees about the sun, is admitted with the sun's direct light, through the little lens, to the dark chamber; and the light, thus augmented, is observed in contrast with a darkness greater than that of a clear nocturnal sky. The entire loss by reflecting and absorbing is manifestly so small, and the light of the sky in the immediate vicinity of the sun, so great, that I can readily believe the waste, in effect, is fully made up; especially when considering the absolute blackness of the ground, upon which the light, in the dark chamber, is projected; and I can find no reason to doubt that the sun would appear as a star of the sixth magnitude, or be only just visible to the unassisted human eye, even setting aside the idea of an extinguishing medium, if removed 1,200,000 times his present distance; and at 100,000 times his present distance, he would only rank as a pretty bright star, of the first magnitude; though his parallax would be double that imputed to any star in the whole heavens. If his intrinsic splendor generally proves to be less than that of those stars whose distances have been measured, we need not infer that it is less than the average of existing stars; for, in case of a diversity among them, bearing any proportion to that among organic bodies, on the face of the earth, or the planets of our system, where the numbers are so comparatively small, the *visible* stars, would, of course, exceed, upon the average, our sun; for, by the laws of perspective, the small ones would be lost to our view, at distances from which the brighter individuals would appear as conspicuous objects.

Such would be the case with telescopic magnitudes, as well as with those visible to the naked eye.

The number of stars visible, by aid of the more powerful telescopes, is far less, in proportion to the power of the instruments, than those visible to the unassisted eye, or with smaller telescopes.

This fact has given rise to the doctrine of an extinguishing medium in space; which is accepted by the most able astronomers as the truth, and has been the foundation of much ingenious reasoning.

Plausible or probable, as this appears, I see no difficulty in understanding that an exceedingly great diversity in the intrinsic brightness of the stellar orbs, promiscuously scattered through space, *might* result in the same appearances as those on which this doctrine is founded. For, at the smaller distances, we should see the whole, both great and small, when using only moderate powers; but in the regions bounding the remotest reach of the great telescopes, though the great and the small might be there, it would be only the great that we should see; and those only as the most minute specks of light that can be imagined.

The vast number of smaller, or more moderate lights, like our sun, which may remain concealed among those of extraordinary splendor, yet so remote as only just sensibly to impress our vision when aided to the utmost that human skill can do, will be better understood when we consider the ratio in which an increase of radius increases the cubic contents of a sphere.

Upon the outer limits of such a sphere as would embrace the great mass of telescopic stars, a moderate depth, extended round the whole, would afford an immense amount of room for stars of all imaginable sizes. I desire to be particularly understood, that it is in those very remote regions, or beyond where any telescope, now in use, can possibly show stars of the average, or smaller sizes, that we may look for the modification introduced, by such supposed diversities, into the investigation of this doctrine of an absorbing medium.

Were all the stars in existence of one pattern, one uniform brightness, scattered broadcast through all space, I think the great telescopes would count up more nearly the numbers belonging theoretically to their powers than they now do.

However, with these suggestions, I leave this interesting branch of my subject for the present.

The ratio, in which the light from a celestial object diminishes with an increase of distance, needs no explaining; and I will close by briefly giving, in tabular form, my own results, with those published by Mr. Bond of the Harvard College Observatory, and by Dr. Wollaston, in vol. cxix of the *Philosophical Transactions of the Royal Society of London*, of comparisons between the bright star α Lyræ and the sun.

To bring the magnitude of our sun to an equality with that of this star, his distance would require to be increased, according to

Wollaston, nearly	425,000	times.
Bond, "	155,000	"
Clark,	102,000	"

The light received from these luminaries differs, according to

Wollaston, as	180,000,000,000	to 1
Bond, "	24,000,000,000	"
Clark, "	10,400,000,000	"

I have alluded to the light in the atmosphere about the sun, as giving an increase to his photometrical force; though I am aware that such must be the case with a star; and it must bear the same proportion to the star's light, that it bears to the sun's light.

The difference, in effect, is here; we have several thousand stars playing into our atmosphere at once; but only one sun.

If the distances imputed to several of the stars, from parallax, can be true, I am sure, those having the taste, talent, and leisure, necessary for following up photometrical researches with effi-

ciency, cannot fail to find our glorious luminary a very small star; and to the human understanding, thus enlightened, more than ever, must the heavens declare the glory of God.

P. S.—Since the above had left my hands for the press, I prepared a close covering for the vertical opening to my dark chamber, with a circular perforation, subtending at the prism an angle of 32′; and substituted for the little lens one having a focal distance of one-eighth of an inch. By this arrangement, with the mirror placed above, and an eye-hole by its side, the sun light would be directed upon the prism, or just beside it, at pleasure.

I assumed that when the pencil was made to fall entirely outside of the lens, I was viewing a portion of the sky just equal in form and area to the sun itself, close by its side.

Allowing the direct light to pass centrally over the prism, I found the image visible for more than one minute after the last direct ray from the sun had left the line of the lens, although reduced nearly 22,000 times.

After proceeding thus far, it appeared to me, that could the sun be reduced to a *minimum visibile*, *without* reflexions, and the lenses so arranged that both eyes could be employed in observing, the results would be more satisfactory.

By removing the object-glass, eight inches in diameter, from the tube of my equatorial, and placing a lens in the eye-tube, one-twentieth of an inch in focal distance, and turning the eye end toward the sun, with the eyes 100 inches from the lens, I obtained such a view as the sun would present if removed 2,000 times his present distance. To accomplish the further necessary reduction, I applied an extension sliding tube carrying a lens one-thirty-fourth of an inch focus.

To my surprise the sun was visible when the distance between the lenses was such as to give a reducing power of two millions. But, upon examination, it appeared that light was copiously reflected upon the lens nearest to the eye, from the inner surface of the bright brass extension tube. After diaphragming and properly darkening this tube, on some occasions of very clear skies, a power of nearly 1,600,000 was required to send the sun entirely out of sight. Were not the use of both eyes, the avoidance of reflexion by the looking-glass and prism, and the increased altitude of the sun sufficient to explain the difference between this and the dark chamber observations, I might add, the angle of aperture of the lens nearest the sun is 80° and used without a screen, while only a much smaller proportion of the bright sky was sent down by the mirror into the prism. Seated comfortably upon the observing chair, with the driving clock acting, the face in the mouth of the tube nearly to the ears, and

a folded blanket drawn over the head, so as to exclude all light, I usually gaze listlessly into total darkness for about two minutes, that the pupils may expand, and the eye become prepared for its work. I then slowly remove or raise the blanket upon one side for the admission of light, barely sufficient to show the direction of the lens. A curious effect is here witnessed. Though no view of the sun had previously been obtained, and the eyes had wandered perhaps many degrees, they are suddenly arrested by the appearance of a good plump sixth magnitude star.

On closely drawing the blanket again, it fades to the faintest perceptible point, or disappears altogether, and the eyes wander from its place in spite of every effort to keep them upon it. But when the slightest ray is again allowed to enter past the head, it is reflected from the lens, and combining with the light transmitted from the sun becomes conspicuous as before.

This I have found to be the case when neither the transmitted nor the reflected light alone could stimulate the visual organs to a recognition of its presence.

Since noticing this fact, I invariably close every avenue to the admission of light about the head, preparatory to the final effort, and if the sun is not seen within five minutes, I give it up, reduce the distance between the lenses about one-twentieth, and try again. My eye gains about its maximum power for such purposes in three minutes. I am on my guard against the consequences of allowing insufficient time. When a view is obtained estimated equal to a faint sixth magnitude, the distance between the lenses is measured, and the reducing power computed. I do not, it will be seen, trust to any comparisons with artificial lights as standards, but make a *minimum visibile* the standard in all cases; which leaves the eyes and attention free to pursue one object at a time. A movable brass plate, with a perforation one-tenth of an inch in diameter, is placed nine inches beyond the lens next the sun, for admitting his direct rays, with only a very narrow annulus of surrounding skylight.

The following results were obtained April 28.

6h 30m A. M.	1,055,360	sky admitted.
6 40	783,100	sky screened off.
12 noon,	1,308,000	sky screened off.
12 10 P. M.	1,574,400	sky admitted.

These morning observations were made for the benefit of a friend, who wished them for a special purpose.

The numbers in the noon observation are very near the maximum exhibited in many extreme efforts, made when the skies were remarkably clear.

It makes an enormous difference, it will be noticed, whether the sun is observed with the atmospheric light screened off or not; but, to give the sun and the star equal conditions, the eye should in both cases be shielded against the light from surrounding regions. If we could condense into a compass of less than the fourth of a second all the sky-light within 40° of a faint star, and add it to the star, it would give a manifold increase to its brightness. This is what occurs in observing the sun without the screen; though the atmospheric light in question is, by day, from the sun alone, but by night, from the host of stars of all magnitudes; which would make the conditions monstrously unequal; and this indicates the importance of clearing it away in both cases as effectually as possible. The method by which it is cleared from the sun is already explained; but for dealing with a star, I remove all the lenses from the finder tube to my equatorial, and place in each end of it, a disk of brass, with a central perforation, one-fifth of an inch in diameter, while another similar disk is placed upon an arm extending beyond the object end of the main tube, ten feet from the eye, upon a direct line with those in the finder. When a star occupies a given point in the field of the telescope, it is also in a line with the centres of these holes. But the plan is faulty; inasmuch as it is going back to the use of one eye; and since the holes must equal in diameter its expanded pupil, they admit sufficient light from the blank sky to be seen, if a sharp effort is made; though when that from a star of the seventh magnitude is brought in with it, an augmentation is quite apparent, and a bright sixth magnitude, like 32 Bootis, is instantly and constantly seen with the single eye, through the screen, with two pieces of plate glass interposed. Mitchell has estimated, from Bouguer's observations, that the sun would equal a star of the sixth magnitude, if he were removed to ten millions of times his present distance, which is nine times as much as could possibly be required, so far as I can understand by these experiments, to give him companionship with the star 32 Bootis.

Cambridgeport, May 26, 1863.